U.S. Plug-In Sales Falter

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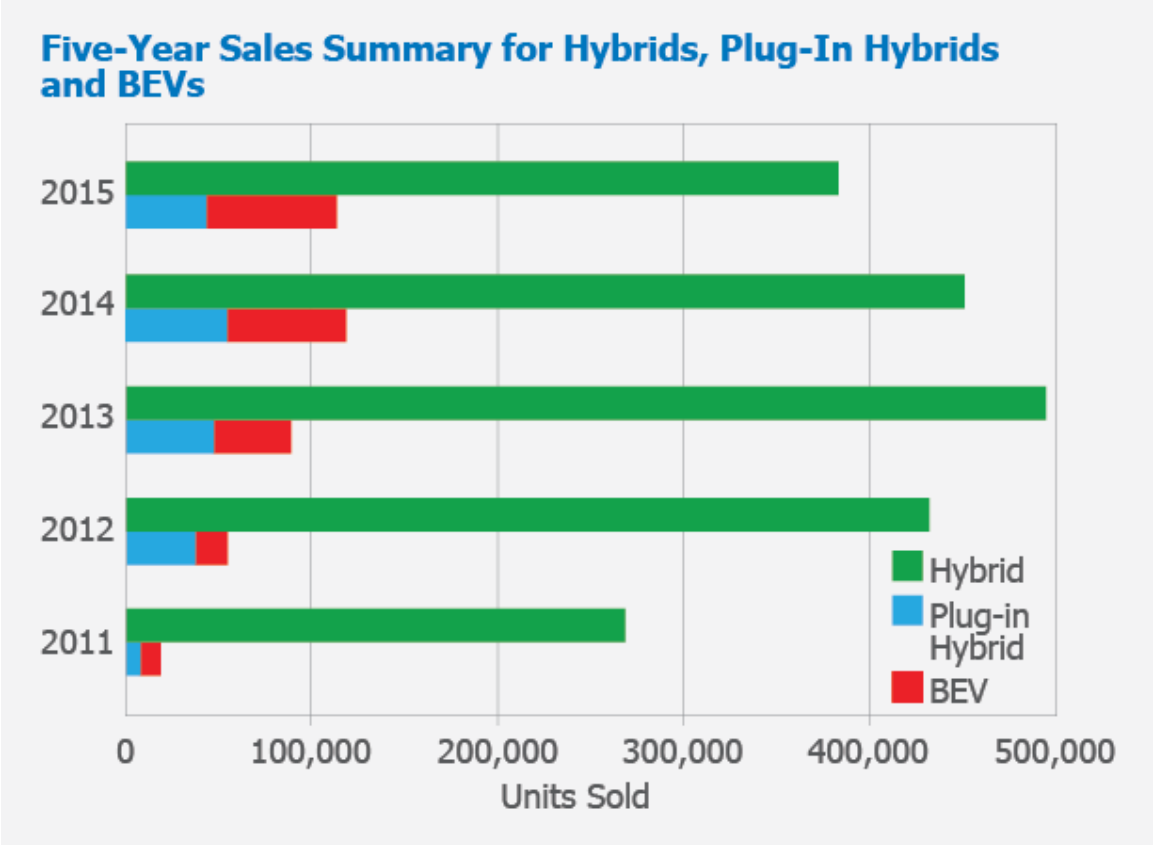

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Introduction

The nation's current plug-in car program has been underway for more than a decade. Certain events date its beginning, such as the formation of Tesla Motor Company in 2003 and the delivery of the Tesla Roadster in 2008; or the introduction of GM's Volt Concept car in early 2007. The first production Chevrolet Volt was shipped in December 2010, the same month that the first Nissan Leaf was shipped. Today there are approximately 27 plug-in models available. About 404,000 plug-in vehicles were shipped from January 2011 through December 2015. [1]

Electrification of transport became a national goal when, on August 4, 2008 presidential candidate Barack Obama gave a talk in Lansing, MI, "We must end the age of oil in our time". Obama described his New Energy for America plan including the elimination of U.S. dependence on Middle Eastern oil within ten years. In this talk he committed to getting one million 150 mile-per-gallon plug-in hybrid vehicles (PHEV) on America's roads by 2015. His program offered a $7,000 tax credit, later changed to a higher purchase rebate. It also provided for more than $4 billion in loans and tax credits to American auto plants and manufacturers to re-tool their factories to build electric cars. Obama also set a goal of increasing fuel economy standards by 4 percent each year, more than twice the long term rate of Miles per Gallon (MPG) improvement of the auto industry. [2]

In spite of billions of dollars of investment, not only in cars but also in batteries and manufacturing facilities, the million car goal was not reached. Sales have been disappointing, compared to the early projections of manufacturers, suppliers, utilities, media outlets, and politicians. Table 1 shows the sales of plug-in cars for the first five full years of shipment (2011-2015). Note that total plug-in hybrid sales (PHEVs) are just under 200,000 units through 2015, one fifth of the Obama original million car goal. Nor do any plug-in models achieve 150 miles per gallon (MPG); the average is less than 50 MPG equivalent.

Sales Summary - Hybrids and Plug-ins 2011-2015 (in 1000s)						
	2011	2012	2013	2014	2015	Total
PHEVs	8	39	49	55	43	194
BEVs	10	14	48	63	72	207
All Plug-ins (PHEVs + BEVs)	18	53	97	119	115	401
Hybrids	269	434	496	452	384	2,036
Hybrids & All Plug-ins	287	487	592	571	500	2,436
All Cars	12,734	14,442	15,532	16,435	17,386	76,530
PHEV-%All Cars	0.1%	0.3%	0.3%	0.3%	0.2%	0.3%
BEVs-%All Cars	0.1%	0.1%	0.3%	0.4%	0.4%	0.3%
All Plug-ins (PHEVs + BEVs)-%All Cars	0.1%	0.4%	0.6%	0.7%	0.7%	0.5%
Hybrids-%All Cars	2.1%	3.0%	3.2%	2.8%	2.2%	2.7%
Hybrids & Plug-ins-%All Cars	2.3%	3.4%	3.8%	3.5%	2.9%	3.2%
Hybids-%Hybrids+Plug-Ins	93.8%	89.2%	83.7%	79.2%	76.9%	83.5%
All Plug-ins Yearly Growth Rate		194.7%	84.0%	22.9%	-2.9%	
Hybrids Yearly Growth Rate		61.6%	14.1%	-8.8%	-15.0%	

Table 1: U.S. Shipments of Hybrid and Plug-in Cars 2011-2015

Plug-in Limitations

Why are sales so much lower than the original projection? One reason might be uncertainty about the actual fuel economy of plug-in cars. The Environmental Protection Agency (EPA) is the responsible organization for establishing the methodology for determining automobile fuel economy and providing the information on the car window sticker. Fuel economy has historically been measured in miles per gallon (MPG). The EPA made a key decision to ignore the fossil fuel energy used to generate electricity, the "fuel" for electric cars, resulting in a Miles per Gallon "equivalent" (MPGeqv or MPGe) rating for such cars that is almost three times what it would be if power plant CO_2 was included.

The challenge to the EPA MPGe method has a long history. A cartoon in the Denver Post in 2010 succinctly summarizes the issue (see Figure 1).

Figure 1: Relationship of Power Plants to Plug-in Cars

Danish author Bjorn Lomborg has criticized the plug-in car concept for some years. In a 2015 USA Today article, "Electric car benefits? Just myths," [3] Lomborg recommends that we stop our green worship of the electric car, arguing against its cost and the small reductions of CO_2 achieved. He points out those electric cars are advertised as zero-emissions vehicles, but in reality they only shift emissions to electricity production, with most electricity coming from the burning of fossil fuels. He quotes green venture capitalist Vinod Khosla who says that "Electric cars are coal-powered cars."

Lomborg makes a few comparisons noting that the Nissan Leaf, over a 90,000-mile lifetime, will emit 31 metric tons of CO_2, based on emissions from its production, its electricity consumption at average U.S. fuel mix, and its ultimate scrapping. He says a comparable diesel Mercedes CDI A160 over a similar lifetime will emit 3 metric tons more across its production, diesel consumption and ultimate scrapping. He notes that results are similar for the top-line Tesla car, emitting 44 metric tons, about 5 metric tons less than a similar Audi A7Quattro. His analysis uses Life Cycle Assessments for the cars mentioned.

Other Plug-in Research

Lomborg is controversial but his arguments are sound and he is not alone in his perspective. A June 2015 report, "Regional Variability and Uncertainty of Electric Vehicle Life Cycle CO_2 Emissions across the United States", produced by researchers from Carnegie Melon provides a more detailed and extensive explanation of the argument proposed by Lomborg[4].

The researchers computed specific life cycle CO_2 emissions per mile traveled for plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) across the United States taking into account regional electricity emission factors, regional boundaries, and charging schemes. Figure 2 is a graphic illustration of the differences in regions and the different ways of charging. (Red is more CO_2 and green is less CO_2.)

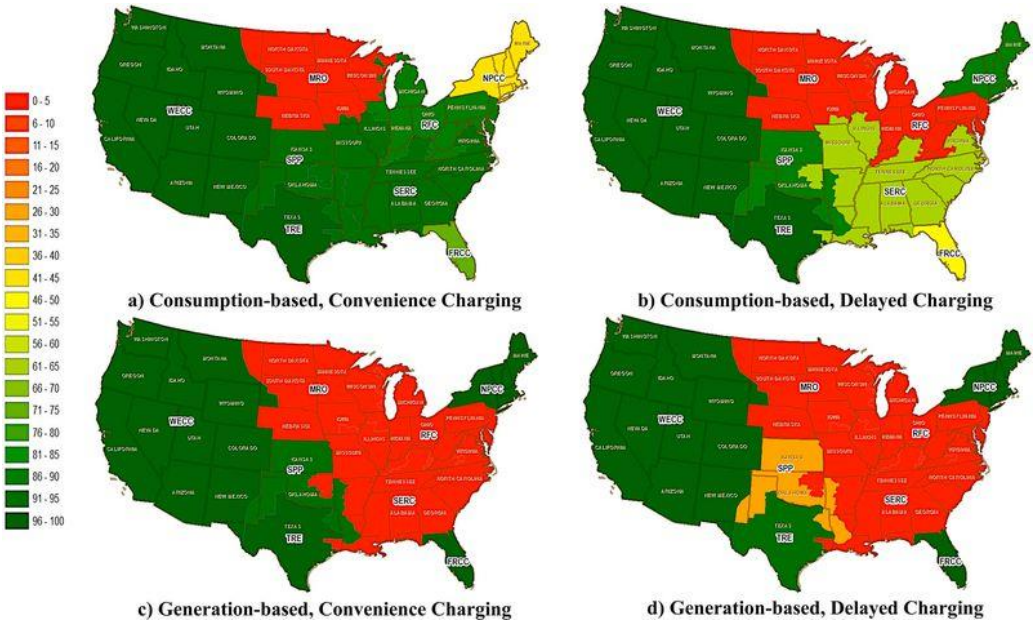

Figure 2: Regional Measurements for Energy and Emissions

Some interesting points from this study include:

(1) "delayed charging (i.e., starting at midnight) leads to higher emissions in most cases due largely to increased coal in the marginal generation mix at night;

(2) the Chevrolet Volt has higher expected life cycle emissions than the Toyota Prius Hybrid Electric Vehicle (the most efficient gasoline vehicle) across the U.S. in nearly all scenarios;

(3) the Nissan Leaf BEV has lower life cycle emissions than the Prius in the western U.S. and in Texas, but the Prius has lower emissions in the northern Midwest regardless of the assumed charging scheme and marginal emissions estimation method;

(4) in other regions the lowest emitting vehicle depends on charge timing and emission factor estimation assumptions."

This report is the latest of many addressing the different fuel mixes in different regions. A “State of Charge” report entitled *Electric Vehicles’ Global Warming Emissions and Fuel-Cost Savings across the United States*[5] was published in June 2012 by the Union of Concerned Scientists (UCS). Figure 3 illustrates the difference in miles per gallon equivalent as a function of the CO_2 emissions from different regions for a Nissan Leaf.

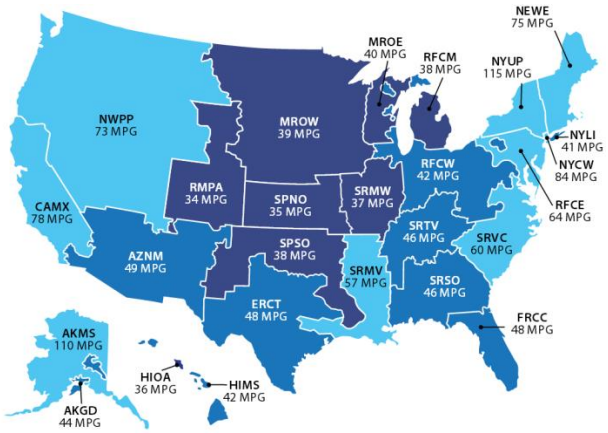

Figure 3: UCS State of Charge 2012 Report for Nissan Leaf

An update to the State of Change report was prepared in 2014.[6] Figure 4 shows the changed values which are based in part on an upgraded 2013 model of the Nissan Leaf, which improved its previous rating of .34 kWh/mile (a measure of how much electricity is consumed for traveling 1 mile) to a rating of .30 kWh/mile. The report also used more recent data for average power plant emissions which declined between the first report and the second one.

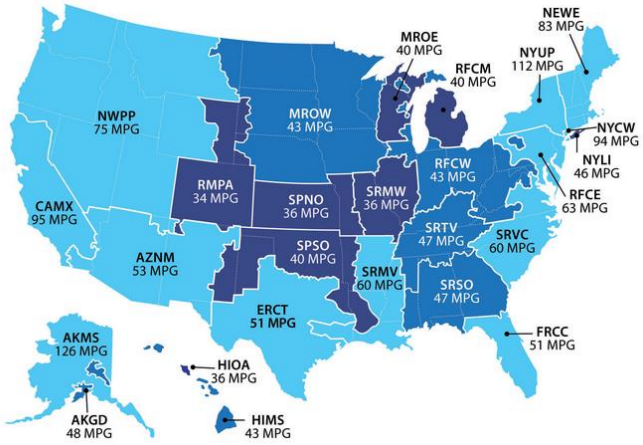

Figure 4: UCS State of Charge 2014 Report for Nissan Leaf

The Department of Energy has developed an on line tool that shows the differences between hybrid electric vehicles (HEVs), plug-in hybrids (PHEVs) and battery electric vehicles (EVs) as well as Conventional Gas Vehicles. [7] This is illustrated in Figure 5.

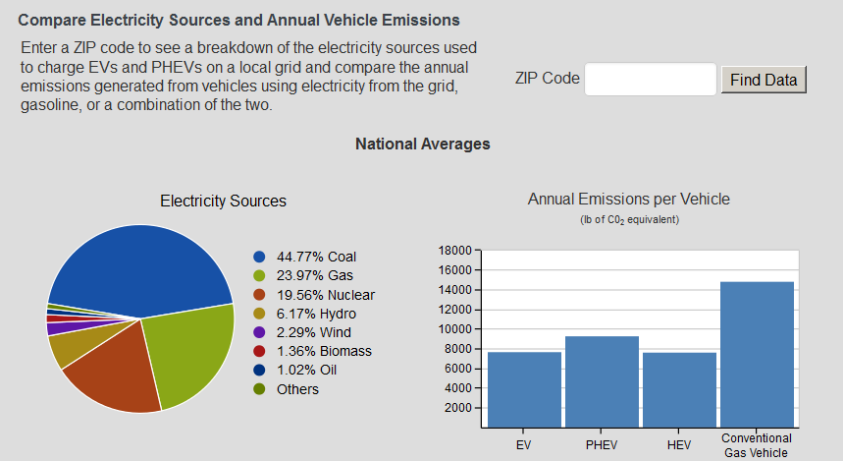

Figure 5: Comparison of EV, PHEV, HEV, with Conventional Cars

The report includes the CO_2 generated for a 100 mile trip averaged for the U.S. for the four different kinds of drive trains. Figure 6 shows that a HEV emits less CO_2 than the other three options.

Emissions and Fuel Cost for a 100-Mile Trip	
Vehicle (compact sedans)	**Greenhouse Gas Emissions (pounds of CO_2 equivalent)**
Conventional	99 lb CO_2
Hybrid Electric	51 lb CO_2
Plug-in Hybrid Electric	61 lb CO_2
All-Electric	54 lb CO_2

Figure 6: Pounds of CO_2 Generated for a 100 miles trip for four drive trains

But going back to the original Obama proposal, whatever happened to the 150 mpg plug-in hybrid? It never materialized. The best representations for the three classes of cars are the Toyota Prius HEV, the Chevrolet Volt PHEV, and the Nissan Leaf BEV. For the 2015 models, the grams per mile (g/m) are: Prius-218 g/m, Leaf-190 g/m and Volt-250 g/m. The cars are quite close in fuel economy performance when using CO_2 emissions to determine Miles per Gallon Equivalent (MPGe). Some researchers have suggested a different term – Miles per Gallon Equivalent- Greenhouse Gases or MPGeghg. Another label option is MPGeCO_2.

There is also sufficient data now to test the Obama goal of increasing fuel economy standards by 4% each year. This is a very ambitious rate of improvement and unlikely to be achieved without significant restrictions on weight and horsepower. The highest MPG car is the Prius, which has improved performance over a 15 year period at between 1% and 2% yearly, the best in the industry to date. This shows that 4% was not realistic.

Reviewing Conventional Hybrid Sales 2000-2015

Table 2 shows conventional hybrid model sales in the U.S. beginning in the year 2000. The different models are ordered from top to bottom, first by year of introduction and second by sales volume. The first appearance of a sales number in a row represents the year of first shipment of the model.

This table provides a visual reference of historical first customer shipment and sales histories. The right-most column shows the total cars sold over a model's lifetime (through 2015) and allows comparisons of the sales of different models. For example, the table shows that total Prius Liftback lifetime sales were slightly more than 1.6 million cars while the total Chrysler Aspen lifetime sales were 46 cars. (Liftback is the term for the current Prius, used to distinguish this model from the Prius c, Prius v, and Prius PIP). The bottom row shows annual sales of all hybrids.

Most early entrants in a new market do not succeed. In addition, some cars that have been classified as hybrids do not fit in the high-mileage hybrid architecture. These include the so-called mild hybrids (Saturn Aura, Saturn Vue, Chevrolet Malibu, Chevrolet Tahoe, GMC Yukon) made by GM. Of the 60 models listed in Table 2, 41 of them fit in the categories of low sales, canceled models, or are not really hybrids but "mild" hybrids. This is a relatively high number of unsuccessful models for a new drive train concept but it may be typical of a new technology introduction.

Some very recent cars are not included in this table since they were announced in late 2015 and have very limited sales to date, such as the Toyota RAV4 hybrid.

Cars in Table 2 with an asterisk identify a group of cars which are summarized in Table 4 as the Least Successful Hybrids. An example from the Vehicle (MPG) column is the Honda Insight. Its entry is written as Honda Insight 1(53)*. About two thirds of the models have an asterisk designation, marking the least popular models. Cars without asterisks are summarized in Table 3 as Most Successful Hybrids and identify the more popular models.

U.S. Hybrids Sales by Date of Introduction 2000-2015 (in 1,000s) Table 2												
Vehicle(mpg)	**2000-2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Toyota Prius(41)	228	107	181	159	140	141	136	148	145	123	114	1,621
Honda Insight 1(53)*	13	1	0	0	0	0	0	0	0	0	0	14
Honda Civic(40)	87	31	33	31	15	7	5	7	8	5	5	234
Ford Escape(27)*	22	20	21	17	15	11	10	1	0	0	0	118
Honda Accord 1(28)*	18	6	3	0.2	0	0	0	0	0	0	0	27
Lexus RX400/450h(25)	21	20	17	15	14	15	11	12	11	9	8	154
Toyota Highlander(27)	18	31	22	19	11	7	5	6	5	4	4	133
Mercury Mariner(28)*	1	3	4	2	2	1	0	0	0	0	0	13
Toyota Camry(34)		31	54	46	23	15	9	46	44	40	31	339
Lexus GS 450h(23)*		2	2	1	0.5	0.3	0.3	1	1	0.2	0.1	7
Nissan Altima(34)*			8	9	9	7	3	0.1	0	0	0	37
Saturn Vue(26)*			4	3	3	0	0	0	0	0	0	10
Lexus LS600hL(21)*			1	1	0.3	0.1	0.1	0.1	0.1	0.1	0	3
Saturn Aura(27)*			1	0.3	1	0.1	0	0	0	0	0	2
Chevy Malibu(27)*				2	4	0.4	0.02	17	14	1	0	38
Chevy Tahoe(21)*				4	3	1	1	1	0.4	0.1	0	10
GMC Yukon(21)*				2	2	1	1	1	0.3	0	0	7
Cadillac Escalade(20)*				1	2	1	1	1	0.4	0	0	6
Chrysler Aspen(21)*				0.05	0	0	0	0	0	0	0	0.05
Ford Fusion(39)					16	21	11	14	37	35	25	159
Honda Insight 2(41)*					21	21	16	6	5	4	1	73
Lexus 250h(35)*					2	11	3	1	0.01	0	0	16
Chevy Silverado(21)*					2	2	1	0.5	0.1	0	0	5
Mercury Milan(39)*					1	1	0	0	0	0	0	3
Honda CRZ(37)						5	11	4	5	4	3	32
Lincoln MKZ(39)						1	6	6	7	10	8	39
Porsche Cayenne(21)*						0.3	2	1	1	1	0	4
Mercedes S400HV(21)*						1	0.3	0.1	0.1	0	0	1
Mazda Tribute(32)*						1	0.5	0.1	0.0	0	0	1
GMC Sierra(21)*						1	0.2	0.5	0.1	0	0	1
Mercedes ML450H(22)*						1	0.0	0.0	0.0	0	0	1
BMW X6(18)*						0.2	0.04	0	0	0	0	0.3
BMW Hybrid 7(20)*						0.1	0.3	0.2	0.03	0	0	1
Toyota Prius v(42)							8	41	35	31	29	144
Hyunda Sonata(36)							20	21	22	21	20	103
Lexus CT200h(42)							14	18	15	18	15	79
Kia Optima(36)							0.40	10	14	14	11	50
Buick Lacrosse(29)*							2	12	7	7	4	32
Buick Regal(29)*							0.12	3	3	1	0	6
infiniti m35h Q70 (29)*							0.38	1	0.5	0.2	0	2
VW Touareg(21)*							0.39	0.3	0.1	0	0	1
Porsche Panamera(25)*							0.05	1	0.1	0	0	1
Toyota Prius c(50)								36	42	41	38	157
Ford C-Max(43)								11	28	19	14	72
Lexus ES 300h(40)								7	17	15	11	50
Toyota Avalon(40)								1	16	17	12	46
VW Jetta(45)*								0.2	6	2	1	8
Acura ILX(38)*								1	1	0.4	0.0	3
BMW 335ih(26)*								0.4	1	0.2	0	1
Audi Q5(26)*								0.3	1	0.3	0.1	2
BMW 535ih(26)*								0.4	1	0.1	0	1
Honda Accord 2(47)									1	14	11	26
Infiniti QX60(26)									1	2	2	5
Nissan Pathfinder(26)									0.3	2	2	5.1
Infiniti Q50(31)									0.3	3	4	7.8
Mercedes E400H(26)*									0.3	0.2	0	0.5
Chevrolet Impala(29)*									0.1	1	0.3	0.9
Subaru Crosstrek Hybrid (31)*										8	6	13.5
Lexus NX 300hHybrid (33)										0.4	2.6	2.9
Acura RLX Hybrid (30)*										0.1	0.3	0.4
Total	407	253	352	314	286	275	278	434	496	452	384	3,930

Table 2: US Hybrid Sales by Year and Total 2000 – 2015

Reviewing Most Successful Hybrids 2000-2015

Table 3 represents a subset of 21 of the 60 hybrid cars listed in Table 2. These are the most successful cars in terms of sales. These 21 are the "hybrid winners" of the period 2000-2015.

U.S. Hybrids Sales by Date of Introduction 2000-2015 Most Successful Table 3 (in 1000s)												
Vehicle(mpg)	**2000-2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Toyota Prius(41-50)	228	107	181	159	140	141	136	148	145	123	114	1,621
Honda Civic(40-45)	87	31	33	31	15	7	5	7	8	5	5	234
Lexus RX400/450h(25-30)	21	20	17	15	14	15	11	12	11	9	8	154
Toyota Highlander(27-28)	18	31	22	19	11	7	5	6	5	4	4	133
Toyota Camry(34-41)		31	54	46	23	15	9	46	44	40	31	339
Ford Fusion(39-42)					16	21	11	14	37	35	25	159
Honda CRZ(37)						5	11	4	5	4	3	32
Lincoln MKZ(39-40)						1	6	6	7	10	8	39
Toyota Prius v(42)							8	41	35	31	28	144
Hyunda Sonata(36-38)							20	21	22	21	20	103
Lexus CT200h(42)							14	18	15	18	15	79
Kia Optima(36)							0.4	10	14	14	11	50
Toyota Prius c(50)								36	42	41	38	157
Ford C-Max(43)								11	28	19	14	72
Lexus ES 300h(40)								7	17	15	11	50
Toyota Avalon(40)								1	16	17	12	46
Honda Accord 2(47)									1	14	11	26
Infiniti QX60(26)									1	2	2	5
Nissan Pathfinder(26)									0	2	2	5
Infiniti Q50(31)									0	3	4	8
Lexus NX 300h Hybrid (33)										0.4	3	2.9
Subtotal-21 mdls-88% of sales	353	221	308	271	219	213	237	386	454	426	370	3,459
Toyota/Lexus-79% of sales	266	190	275	240	188	178	184	313	331	297	263	2,726

Table 3: 21 Most Successful Hybrids

The top three models in terms of lifetime sales are the Prius Liftback, the Toyota Camry, and the Honda Civic (one of the very first hybrids made). The "Vehicle" column includes the miles per gallon (MPG) in parenthesis next to the name. For the top six models, the MPG includes both the original MPG of these cars as well as the most recent MPG for 2015 models. For example the Toyota Prius MPG field is written as (41-50), showing the MPG in 2000 was 41 while the latest 2015 model has a 50 MPG rating. There has been about a 20% improvement in MPG from the early hybrid versions to the current 2015 versions.

Note that the combination of Toyota and Lexus car sales (Lexus being the luxury car division of Toyota Motor Corporation) represent about 80% of total sales of the 19 cars listed. Since the Toyota Corporation (including Toyota brands and Lexus brands) has about 70% of the total market, the 80% market share of the more successful models implies Toyota has even a higher percentage of this market for its hybrid products.

Reviewing Least Successful Hybrids 2000-2015

Table 4 is a list of the least successful hybrid models. There are 39 models that fit in this category. Note that the Toyota share of market for this group is only 6% of sales.

U.S. Hybrids Sales by Date of Introduction 2000-2015 Least Successful Table 4 (in 1000s)												
Vehicle(mpg)	2000-2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Honda Insight 1(53)*	13	1	0	0	0	0	0	0	0	0	0	14
Ford Escape(27)*	22	20	21	17	15	11	10	1	0	0	0	118
Honda Accord 1(28)*	18	6	3	0	0	0	0	0	0	0	0	27
Mercury Mariner(28)*	1	3	4	2	2	1	0	0	0	0	0	13
Lexus GS 450h(23)*		2	2	1	0	0	0	1	1	0	0	7
Nissan Altima(34)*			8	9	9	7	3	0	0	0	0	37
Saturn Vue(26)*			4	3	3	0	0	0	0	0	0	10
Lexus LS600hL(21)*			1	1	0	0	0	0	0	0	0	3
Saturn Aura(27)*			1	0	1	0	0	0	0	0	0	2
Chevy Malibu(27)*				2	4	0	0	17	14	1	0	38
Chevy Tahoe(21)*				4	3	1	1	1	0	0	0	10
GMC Yukon(21)*				2	2	1	1	1	0	0	0	7
Cadillac Escalade(20)*				1	2	1	1	1	0	0	0	6
Chrysler Aspen(21)*				0.05	0	0	0	0	0	0	0	0.05
Honda Insight 2(41)*					21	21	16	6	5	4	1	73
Lexus 250h(35)*					2	11	3	1	0	0	0	16
Chevy Silverado(21)*					2	2	1	0	0	0	0	5
Mercury Milan(39)*					1	1	0	0	0	0	0	3
Porsche Cayenne(21)*						0.3	2	1	1	1	0	4
Mercedes S400HV(21)*						1	0	0	0	0	0	1
Mazda Tribute(32)*						1	0	0	0	0	0	1
GMC Sierra(21)*						1	0	0	0	0	0	1
Mercedes ML450H(22)*						1	0	0	0	0	0	1
BMW X6(18)*						0.25	0.04	0	0	0	0	0.3
BMW Hybrid 7(20)*						0.10	0.34	0.23	0.03	0	0	1
Buick Lacrosse(29)*							2	12	7	7	4	32
Buick Regal(29)*							0.1	3	3	1	0	6
Infiniti m35h Q70 (29)*							0.4	1	0	0	0	2
VW Touareg(21)*							0.4	0.3	0.1	0	0	1
Porsche Panamera (25)*							0.1	0.6	0.1	0	0	1
VW Jetta(45)*							0.0	0.2	5.7	2	1	8
Acura ILX(38)*								1	1	0	0	3
BMW 335ih(26)*								0.4	0.9	0.2	0	1
Audi Q5(26)*								0	0.9	0.3	0	2
BMW 535ih(26)*								0.4	0.5	0.1	0	1
Mercedes E400H(26)*								0.0	0.3	0.2	0	0.5
Chevrolet Impala(29)*									0.1	0.6	0	1
Subaru Crosstrek Hybrid (31)*										8	6	14
Acura RLX Hybrid (30)*										0.1	0.3	0.4
Subtotal-39mdls-12% of sales	54	31	45	43	67	62	41	48	42	26	13	472
Toyota/Lexus-6% of sales	0	2	3	2	3	11	3	1	1	0		25

Table 4: 39 Least Successful Hybrids

3.5 million units were sold of the most successful hybrid group of 21 cars versus 0.47 million cars sold for the 39 least successful cars. Average sales per model for the 21 successful cars was about 165,000 units. On average the 39 least successful cars sold about 12,000 cars each.

Hybrid Sales and Trends by Company

The following tables show comparisons of hybrid cars by company. Each table shows the units sold yearly for the period 2010-2015. (This information is taken from Table 2).The bottom row, "Take Rate – Hybrids" and "Take Rate – All Cars", are the percent of the total hybrid sales captured and the percent of the total of all cars captured for each year. The order presented is by manufacturer, beginning with hybrid market leader, Toyota. It includes the miles per gallon for each model next to the name. The cars are listed from top to bottom in order of 5 year total units.

Each table is divided into two sections – "Sustaining/Growing" and "Declining/Disappearing." Some of the models have been withdrawn by the manufacturer – others have been removed based on the author's projections. The Sustaining/Growing category includes the 21 models shown in Table 3. The Declining/Disappearing category consists of the 39 models from Table 4.

Toyota

Toyota hybrid cars are available under two different brand names – Toyota and Lexus. Toyota has three other brands that do not include hybrid versions. Table 5 shows the units Toyota sold in the six year period from 2010-2015.

TOYOTA						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**5 yr. Total**
	Units	**Units**	**Units**	**Units**	**Units**	**Units**
Sustaining/Growing						
Toyota Prius (50)	136,463	147,503	145,172	122,776	113,829	665,743
Toyota Camry(41)	9,241	45,656	44,448	39,515	30,640	169,500
Toyota Prius c(50)		35,733	41,979	40,570	38,484	156,766
Toyota Prius v(42)		40,669	34,989	30,762	28,290	134,710
Toyota Avalon(40)		747	16,468	17,048	11,956	46,219
Lexus CT 200h(42)	14,381	17,671	15,071	17,673	14,657	79,453
Lexus RX400/450h(30)	10,723	12,223	11,307	9,351	7,722	51,326
Lexus ES 300h(40)		7,041	16,562	14,837	11,241	49,681
Toyota Highlander(28)	4,549	5,921	5,070	3,621	4,015	23,176
Lexus NX 300 (33)				354	2,513	2,867
Sub Total	175,357	313,164	331,066	296,507	263,347	1,379,441
Declining/Disappearing						
Lexus 250H(35)*	2,864	649	5	0	0	3,518
Lexus GS450H(31)*	282	607	522	183	91	1,685
Lexus SL 600HL(20)*	84	54	115	65	47	365
Sub Total	3,230	1,310	642	248	138	5,568
Total	178,587	314,474	331,708	296,755	263,485	1,385,009
Take Rate - Hybrids	66.44%	72.38%	66.92%	65.63%	68.70%	
Take Rate - All Cars	1.40%	2.18%	2.14%	1.81%	1.52%	
All Hybrids	268,807	434,498	495,685	452,152	383,540	
All Vehicles	12,734,356	14,441,814	15,531,609	16,435,286	17,386,331	

Table 5: Toyota/Lexus Hybrid Sales 2011-2015

Ford

Ford took U.S. hybrid market share from Toyota with original high sales of the Fusion and C-Max models. U.S. sales for these two cars more than doubled from 2012 to 2013. But sales declined for both models from 2013 to 2014 and from 2014 to 2015 reflecting a reduction in actual MPG ratings. The first column of Table 5 shows the MPG of the cars in parenthesis. In the case of Ford (Table 6), two numbers are shown for the first three cars in this column. One represents the original MPG and the second the downgraded numbers. The Ford Fusion MPG was reduced from 47 to 42, the Ford C-max from 47 to 40 and the Lincoln MKX from 45 to 40.

FORD Table 6						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**5 yr. Total**
	Units	**Units**	**Units**	**Units**	**Units**	**Units**
Sustaining/Growing						
Ford Fusion(47-42)	11,286	14,100	37,270	35,405	24,681	122,742
Ford C-Max(47-40)		10,935	28,056	19,162	14,177	72,330
Lincoln MKZ(45-40)	5,739	6,067	7,469	10,033	8,403	37,711
Subtotal	17,025	31,102	72,795	64,600	47,261	232,783
Declining/Disappearing						
Ford Escape(32)*	10,089	1,441	0	0	0	11,530
Mercury Milan(39 *	0	0	0	0	0	0
Mercury Mariner(27)*	0	0	0	0	0	0
Subtotal	10,089	1,441	0	0	0	11,530
Total	27,114	32,543	72,795	64,600	47,261	244,313
Take Rate - Hybrids	10.09%	7.49%	14.69%	14.29%	12.32%	
Take Rate - All Cars	0.21%	0.23%	0.47%	0.39%	0.27%	
All Hybrids	268,807	434,498	495,685	452,152	383,540	
All Vehicles	12,734,356	14,441,814	15,531,609	16,435,286	17,786,331	

Table 6: Ford Family Hybrid Sales 2011-2015

Ford has a long history in conventional hybrids, having successfully developed and marketed the Ford Escape Hybrid with more than 22,000 sold from 2004 through 2012. The Ford Fusion Hybrid and the C-Max Hybrid are the company's latest hybrid offerings but they suffered from overstated MPG claims. According to Consumer Reports, the Ford Fusion Hybrid and Ford C-Max Hybrid have, of all current hybrid models, the largest discrepancies between overall MPG results and the estimates published by the EPA. [8]

Ford will continue to have some moderate success with its hybrids but not based on exceptional mileage performance as was earlier claimed. In October 2014, the company changed its ads for the C-Max from "high MPG performance" to "fun to drive." [9] In March of 2015, Raj Nair, Ford group vice president of Global Product Development announced that the company is "very well established" with its hybrid and electric-drive technology, so well established that it's now time for Ford to turn its attention to performance, meaning acceleration not miles per gallon. Nair noted that sales of performance vehicles are up 70% in the US since 2009, Nair said that the high performance vehicles draw customers that in general are younger and better educated.[10] This could be a rationale for the sales decline. Ford is presumably developing replacement versions with higher MPG but this will take some time.

Honda

Honda was the second manufacturer in the world to develop hybrid cars and for years was second to Toyota. Its hybrid cars were eventually outclassed by Toyota and its sales have declined steadily (Table 7). Sales of the Insight have declined to the extent that the model was discontinued. The venerable Civic is still sold in hybrid and conventional versions. Newer Honda models such as the Accord have a more efficient drive train and Honda may be able to make a comeback.

HONDA Table 7						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**5 yr. Total**
	Units	**Units**	**Units**	**Units**	**Units**	**Units**
Sustaining/Growing						
Honda Civic(44)	4,703	7,156	7,719	5,070	4,887	29,535
Honda CRZ(37)	11,330	4,192	4,550	3,562	3,073	26,707
Honda Accord 2(47)			979	13,977	11,065	26,021
Acura RLX(34)				133	250	383
Subtotal	16,033	11,348	13,248	22,742	19,275	82,646
Declining/Disappearing						
Honda Insight 1(53)*						0
Honda Insight 2(42)*	15,549	5,846	4,802	3,965	1,458	31,620
Acura ILX(38)*		972	1,461	379	22	2,834
Subtotal	15,549	6,818	6,263	4,344	1,480	34,454
Total	31,582	18,166	19,511	27,086	20,755	117,100
Take Rate - Hybrids	11.75%	4.18%	3.94%	5.99%	5.41%	
Take Rate - All Cars	0.25%	0.13%	0.13%	0.16%	0.12%	
All Hybrids	268,807	434,498	495,685	452,152	383,540	
All Vehicles	12,734,356	14,441,814	15,531,609	16,435,286	17,386,331	

Table 7: Honda and Acura Hybrid Sales 2011-2015

Beginning in the late 1990s, with the birth of the hybrid, Honda sold about 2/3rds as many hybrids as Toyota. But since 2005, Toyota has increased its hybrid market share relative to Honda due to much better technology. In the first half of 2014, Toyota sold 665,740 hybrid vehicles globally, compared to Honda's 158,696 hybrids globally, illustrating Toyota's dominance. [11]

Although the company has sold over one million hybrids worldwide, its share jumped two percentage points from 2013 to 2014 with the success of a new version of the Honda Accord hybrid. This car, at 47 MPG, is second only to the Prius Liftback and Prius c in terms of MPG ratings.

Hyundai/Kia

These two Korean manufacturers share a common drive train. The Kia Optima is a version of the Hyundai Sonata (Table 8) and Hyundai holds a significant stock position in Kia. Both companies have admitted to overstating MPG ratings for several models and paid massive penalties.[12] This experience points out that MPG testing is not done by the EPA but by the manufacturer. The MPG for both cars has been restated and both cars continue to sell reasonably well. However, their performance is lower than their main competitors, both of their hybrid models getting 38 MPG. The main Ford hybrid models get 40-42 MPG, the main Honda hybrid models get 44-47 MPG, and the main Toyota hybrid models get 40-50 MPG.

Note that the company currently has an 8% market share, third after Toyota and Ford. The company has announced a new line of low emissions cars, the IONIQ, for delivery in 2016.

HYUNDIA/KIA Table 8						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**5 yr. Total**
	Units	**Units**	**Units**	**Units**	**Units**	**Units**
Sustaining/Growing						
Hyundai Sonata(38)	19,673	20,754	21,761	21,052	19,908	103,148
Kia Optima(38)	403	10,084	13,919	13,776	11,492	49,674
Total	20,076	30,838	35,680	34,828	31,400	152,822
Take Rate - Hybrids	7.47%	7.10%	7.20%	7.70%	8.19%	
Take Rate - All Cars	0.16%	0.21%	0.23%	0.21%	0.18%	
All Hybrids	268,807	434,498	495,685	452,152	383,540	
All Vehicles	12,734,356	14,441,814	15,531,609	16,435,286	17,386,331	

Table 8: Hyundai/Kia Hybrid Sales 2011-2015

General Motors (GM)

GM conventional hybrid sales have declined steadily, as shown in Table 9. This is not surprising since GM made a vital strategic decision to focus on plug-in hybrids like the Volt and battery electric cars such as the Spark and did not develop conventional hybrid models. The company attempted to enhance its hybrid position by offering what is called a Mild Hybrid. These cars provide one or two of the functions of a high fuel economy hybrid. It is not expected that mild hybrids will affect hybrid sales since they represent only a tiny part of the hybrid market. They include the Chevy Malibu, Buick Lacrosse and Buick Regal – the top sellers.

GM has announced a 47 MPG Malibu in 2015 for delivery in 2016. This is a big step in performance from the mild hybrids, which ranged from 21 to 29 MPG. This may imply a strategic shift for the company. [13]

GM Table 9						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**5 yr. Total**
	Units	**Units**	**Units**	**Units**	**Units**	**Units**
Declining/Disappearing						
Buick Lacrosse(29)*	1,801	12,010	7,133	7,353	4,042	32,339
Chevy Malibu(29)*	24	16,664	13,779	1,018	59	31,544
Buick Regal(29)*	123	2,564	2,893	662	186	6,428
Cadillac Escalade(21)*	819	708	372	41	7	1,947
Chevy Silverado(21)*	1,001	469	104	24	2	1,600
Chevy Tahoe(21)*	519	533	376	65	8	1,501
GMC Yukon(21)*	598	560	288	31	10	1,487
Chevy Impala(29)*	0	0	56	565	300	921
GMC Sierra(21)*	164	471	65	6	1	707
Saturn Aura(27)*	0	0	0	0	0	0
Saturn Vue(26)*	0	0	0	0	0	0
Total	2,282	2,033	889	691	321	6,216
Take Rate - Hybrids	0.85%	0.47%	0.18%	0.15%	0.08%	
Take Rate - All Cars	0.02%	0.01%	0.01%	0.00%	0.00%	
All Hybrids	268,807	434,498	495,685	452,152	383,540	
All Vehicles	12,734,356	14,441,814	15,531,609	16,435,286	17,386,540	

Table 9: GM Hybrid Sales 2011-2015

Nissan

Nissan made a major strategic decision to compete in the conventional battery electric car market with its Leaf product just as GM did for the plug-in hybrid market with its Volt model. Nissan U.S. Leaf sales were slower to grow than GM's Volt sales since early Leaf sales were in Japan. But in 2013, the Leaf sales surpassed those of the Volt. From 2007-2012 Nissan sold 36,613 units of its Altima hybrid but withdrew it from the market after 2012. An all-new, Nissan-hybrid drive train option is used on the 2014 Pathfinder model. Nissan hybrid sales are shown in Table 10.

Prior to 2011 Ford and Nissan hybrids used technology from the Toyota Prius under a licensing agreement, including technology for the transmission, power inverter, battery, and charging control unit. Nissan has focused so long on the Leaf and BEV technology that it is unlikely to be able to compete effectively with a conventional hybrid in the near future.

NISSAN Table 10						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**5 yr. Total**
	Units	**Units**	**Units**	**Units**	**Units**	**Units**
Sustaining/Growing						
Infinita Q50(30)			307	3,456	4,012	7,775
Nissan Pathfinder(26)			334	2,480	2,245	5,059
Infinita QX60(26)			676	1,678	2,356	4,710
Subtotal			1,317	7,614	8,613	17,544
Declining/Disappearing						
Nissan Altima(33)*	3,236	103	0	0	0	3,339
Infiniti M35h - Q70(29)*	378	691	475	180	176	1,900
Subtotal	3,614	794	475	180	176	5,239
Total	3,614	794	1,792	7,794	8,789	22,783
Take Rate - Hybrids	1.34%	0.18%	0.36%	1.72%	2.29%	
Take Rate - All Cars	0.03%	0.01%	0.01%	0.05%	0.05%	
All Hybrids	268,807	434,498	495,685	452,152	383,540	
All Vehicles	12,734,356	14,441,814	15,531,609	16,435,286	17,386,331	

Table 10: Nissan and Infiniti Hybrid Sales 2011-2015

BMW

BMW has only a token position in the conventional hybrid market. (Table 11) Their commitment now is to electric cars with the “i” series.

BMW Table 11						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**5 yr. Total**
	Units	**Units**	**Units**	**Units**	**Units**	**Units**
Declining/Disappearing						
BMW 335ih(26)*		402	905	151	30	1,488
BMW 535ih(26)*		404	520	112	25	1,061
BMW Hybrid 7(20)*	338	231	31	45	12	657
BMW X6(18)*	43	4	0	0	0	47
Subtotal	381	1,041	1,456	308	67	3,253
Total	381	1,041	1,456	308	67	3,253
Take Rate - Hybrids	0.14%	0.24%	0.29%	0.07%	0.02%	
Take Rate - All Cars	0.00%	0.01%	0.01%	0.00%	0.00%	
All Hybrids	268,807	434,498	495,685	452,152	383,540	
All Vehicles	12,734,356	14,441,814	15,531,609	16,435,286	17,386,331	

Table 11: BMW Hybrid Sales 2011-2015

VW/Porsche

Hybrid Porsches, Audis and early VWs have not been successful. Surprisingly the Jetta Hybrid, with good MPG is in decline. VW is committed to electrification at this point and is dropping its Porsche hybrid models, replacing them with Plug-in versions. See Table 12.

VW/PORSCHE Table 12						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**5 yr. Total**
	Units	**Units**	**Units**	**Units**	**Units**	**Units**
Declining/Disappearing						
VW Jetta Hybrid(45)*		162	5,655	1,939	740	8,496
Porsche Cayenne(21)*	1,571	1,180	615	650	0	4,016
Audi Q5 Hybrid(26)*		270	854	283	97	1,504
VW Touareg Hybrid(21)*	390	250	118	30	16	804
Porsche Panamera(25)*	52	570	78	0	0	700
Subtotal	2,013	2,432	7,320	2,902	853	15,520
Total	2,013	2,432	7,320	2,902	853	15,520
Take Rate - Hybrids	0.7%	0.6%	1.5%	0.6%	0.2%	
Take Rate - All Cars	0.0%	0.0%	0.0%	0.0%	0.0%	
All Hybrids	268,807	434,498	495,685	452,152	384,404	
All Vehicles	12,734,356	14,441,814	15,531,609	16,435,286	17,386,331	

Table 12: VW and Porsche Hybrid Sales 2011-2015

Mercedes

Mercedes does not offer a good hybrid contender and may have chosen not to compete in the hybrid market but focus on plug-ins. Table 13 shows this direction.

MERCEDES Table 13						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**5 yr. Total**
	Units	**Units**	**Units**	**Units**	**Units**	**Units**
Declining/Disappearing						
Mercedes S400hv(21)*	309	121	64	10	1	505
Mercedes E400H(26)*			282	158	53	493
Mercedes ML450h(22)*	1	20	11	20	10	62
Subtotal	310	141	357	188	64	1,060
Total	310	141	357	188	64	1,060
Take Rate - Hybrids	0.12%	0.03%	0.07%	0.04%	0.02%	
Take Rate - All Cars	0.00%	0.00%	0.00%	0.00%	0.00%	
All Hybrids	268,807	434,498	495,685	452,152	384,404	
All Vehicles	12,734,356	14,441,814	15,531,609	16,435,286	17,386,331	

Table 13: Mercedes Hybrid Sales

Information is not provided on Subaru, who entered the market in 2014. They are new to the hybrid market and their prospects are unclear.

Plug-In (PHEV and BEV) Sales Summary – US

Tesla Motors was formed in 2003 to build a battery electric car using lithium-ion batteries. The company introduced its first product, the Roadster, in 2006 and shipped its first production version of that model in 2008. (Tesla delivered about 2,800 Roadsters and discontinued the product when Model S production began in 2012.) GM began its plug-in hybrid Volt effort in 2006, demonstrated a concept vehicle in January 2007, introduced the production version in September 2008, and shipped the first production cars in December 2010.[14] A rough total development time estimate based on this data is five years to first shipment (2006-2010) followed by five full years of production (2011-2015); thus plug-ins today represent the result of a ten year development program. Table 14 lists the cars sold in the 2011-2015 period. The table is divided into Battery Electric Vehicles (BEVs) and Pluggable Electric Hybrid Vehicles (PHEVs). There are 14 BEV and 13 PHEV models.

BEV AND PHEV SALES: 2011-2015 Table 14								
Manufacturer	**Model**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**	**% Sales**
		Units	**Units**	**Units**	**Units**	**Units**		**2015**
BEVs								
Nissan	Leaf	9,674	9,819	22,610	30,200	17,269	89,572	43.22%
Tesla	Model S		2,400	18,650	16,550	26,400	64,000	30.88%
BMW	i3				6,092	11,024	17,116	8.26%
Fiat	500e			405	1,503	4,516	6,424	3.10%
Ford	Focus		685	1,738	1,964	1,582	5,969	2.88%
Mercedes	Smart EV	388	139	923	2,594	1,387	5,431	2.62%
VW	e-Golf				357	4,232	4,589	2.21%
Chevrolet	Spark			539	1,145	2,629	4,313	2.08%
Mercedes	B-Class ED				774	1,906	2,680	1.29%
Toyota	RAV4 EV		192	1,096	1,184	18	2,490	1.20%
Mitsubishi	i-MIEV	80	588	1,029	196	115	2,008	0.97%
Kia	Soul EV				359	1,015	1,374	0.66%
Honda	Fit EV		93	569	407	2	1,071	0.52%
Tesla	Model X					208	208	0.10%
Total		10,142	13,916	47,559	63,325	72,303	207,245	100.00%
PHEVs								
Chevrolet	Volt	7,671	23,461	23,094	18,805	15,393	88,424	45.67%
Toyota	Prius PlugIn		12,750	12,088	13,264	4,191	42,293	21.84%
Ford	Fusion Energi			6,089	11,550	9,750	27,389	14.15%
Ford	C-Max Energi		2,374	7,154	8,433	7,591	25,552	13.20%
BMW	i8				555	2,265	2,820	1.46%
Cadillac	ELR			6	1,310	1,024	2,340	1.21%
BMW	X5					892	892	0.46%
Porsche	Panamera E-hyb			86	879	407	1,372	0.71%
Porsche	Cayenne E-hyb				112	1,163	1,275	0.66%
Honda	Accord Plug-in			526	449	64	1,039	0.54%
Mercedes	S550					118	118	0.06%
Volvo	XC90					86	86	0.04%
Hyundai	Sonata Plug-in					15	15	0.01%
Total		7,671	38,585	49,043	55,357	42,959	193,615	100.00%

Table 14: Plug-In Sales 2011-2015

What's the Future?

Researchers at Carnegie Mellon University (CMU) published two new policy briefs in June 2015, along with accompanying videos, about the benefits of electrified vehicles and the potential for their adoption in the US. The briefs condense the findings of a number of recent papers published by the CMU Vehicle Electrification Group led by Professor Jeremy Michalek.

The first – *Electric Vehicle Benefits and Costs in the United States* [15] – shows that the benefits of vehicle electrification vary based on vehicle type, driving style, climate, the method of supplying electricity, and time of charge. The report suggests that vehicle adoption should typically be focused on HEVs and PHEVs by city drivers in mild-climate regions with a clean electricity grid, such as San Francisco or Los Angeles. Further, drivers should not be encouraged to charge at night in coal-heavy regions. The second report – *Electric Vehicle Benefits and Costs in the United States* [16] points out that electric vehicles can only make an impact to the extent that consumers adopt them, which is affected by a variety of factors including cost, consumer preferences and policy. One surprising conclusion is that plug-in technology will only be adopted if the price is significantly lower than conventional cars or hybrids. Two short videos by Professor Michalek provide an excellent summary of the situation.[17]

This is not the first time that the U.S. government attempted to set drive train standards. Examples include not only electric cars but diesel hybrids and fuel cell cars. The first attempt to develop battery electric cars (BEVs) began in the early 1990s leading to the delivery of the GM EV1 in late 1996. California required car companies to develop battery electric vehicles. Eleven different models were designed and a total of about 6,000 cars produced. The program was halted due to a lawsuit challenging the program. In 2009 GM entered bankruptcy and its future was determined by negotiations with the federal government which pressured the company to continue its Volt development. There have been billions of dollars in loans and grants given to car companies as well as tax breaks reducing most plug-in car purchases by $7,500. The Congressional Budget Office Report on EVs written in 2012 estimated an ultimate cost of $7.5 billion with no reduction in greenhouse gas emissions. [18] [19]

History shows that new presidents often, in good faith, attempt to make some fundamental breakthrough in car architecture. Under the Clinton administration, a major effort was made to develop diesel plug-in cars. Three "proof of concept" models were developed. The Bush administration cancelled that program and redirected government efforts to supporting fuel cell vehicles. Obama redirected efforts away from the fuel cell technology to plug-in hybrids and battery electric vehicles. In a year or so there may be a new national direction.

Meanwhile, automobile companies continue their core strategies to eventually provide a car for every driver in the world. In the U.S. that implies gasoline engines as the basic technology. Car companies tend to go along with government dictates, particularly if the government provides funding as has been done with plug-ins. It allows them to continue manufacturing the typical mix of gasoline cars while arguing that they are becoming "greener," satisfying the public and the government. But these alternative power trains are not significant to the manufacturers. Car companies learned not to fight these programs, as they did in California during the first EV effort of the 1990s. They have elected to simply go along since the sales volumes of the alternatives have historically been so small that the costs can easily be spread across the huge volume of gasoline cars. This is substantiated by the U.S. 2015 car sales of 17 million conventional cars

compared to about 110,000 plug-in cars. The manufacturers make significant plug-in marketing efforts in order to avoid criticism; but they let the market decide.

The government has even taken the responsibility of providing fuel economy information on the window sticker, required by law to be posted on a window in new cars. If criticism is directed toward the car companies as misrepresenting the plug-in MPG equivalent by ignoring power plant emissions, they can respond that they are simply following the law that gives the government responsibility for calculating the numbers. Car companies are focusing on conventional gasoline cars, providing the features most desired by the consumer, which do not include high MPG at this time. The auto industry's primary emphasis is now on autonomous driving, which will make travel even more convenient leading to more miles driven which also translates into more car purchases. A recent study suggests that autonomous vehicles might add one trillion more vehicle miles traveled each year by 2050.[20]

There is a tremendous amount of marketing of plug-ins by government at all levels, including local communities. Often local or regional governments will buy a few plug-ins for their usage, a strategy also used by some corporations, to promote plug-in cars. Electrification of transportation has become a major proposal for mitigating climate change from all world governments. This focus and the intense publicity gives a somewhat false perspective both about the volume of sales (constantly referred to as "exploding") and the depth of the interest by consumers (small). The publicity can serve to assuage the conscience of the average consumer who has little interest in electric cars by assuming someone else is buying them. Consumers can continue buying gasoline cars, while paying lip service to a possible electric purchase in the future. As long as the sales numbers are ignored, such a "feel-good" strategy can be effective.

One counter argument to current slow sales is that "the grid is growing greener every year!" This holds out hope that at some point in the future electricity will all come from renewables and at that point, electric cars will be the standard. But the actual rate of efficiency improvement of the so-called "greening of the grid" is quite low. The recent rapid growth of solar PV gives the impression that the power utilities are achieving record levels of renewable electricity. However, on a worldwide basis, solar PV provides less than 1% of all energy consumed.

The reality of the sales situations is known to the government at one level while at another level its marketing efforts continue. The Annual Energy Outlook report is prepared by the DOE yearly. For the last three years, it has projected that plug-in hybrids (PHEV) and battery electric cars (BEV) will each achieve about 1% of sales by 2040. This will have little effect on climate change.

The subsidies for plug-ins are substantial. The original Obama program called for subsidizing sales of one million plug-in cars. Unless it is extended, then plug-in cars will have to compete on their merits against hybrid cars. Toyota has made hybrid cars their corporate priority, even cancelling some plug-in models including the Prius Plug-in and the RAV4 EV to make that point. Toyota is building about one million hybrids a year spread across several different models and the company has committed to providing a hybrid version of each of its conventional models. In its home country of Japan, hybrid sales are about 20% of total car sales, compared to about 2% in the U.S. Toyota gets most of these orders. Prius sales rates in Japan, a country with a third of the U.S. population, are running about the same for the Prius Liftback model, while the super-efficient Prius c sales in Japan are five times the Prius c sales in the U.S. [21]

There are two other considerations – depreciation and the impact of subsidies. Recently a report noted that plug-in cars have significant first year depreciation.[22] They depreciate much faster than conventional cars or hybrids. Subsidies play a key role in sales. Georgia subsidized electric cars for years but when the subsidy was removed, sales dropped precipitously, some models by more than 90%. [23] [24]

It is also important to understand that the financial subsidies for these cars tend to go to high income households. [25] There is a debate over whether the majority of people who receive tax credits really need them. 60 percent of $18 billion in clean-energy tax credits distributed by the Federal government between 2006 and 2012 went to the top income quintile--households making more than $200,000 per year. Credits for plug-in cars were the single incentive that proved to be most concentrated at the upper end of the income spectrum. Two tax credits aimed at green cars--the Alternative Motor Vehicle Credit (AMVC) and the Qualified Plug-In Electric Drive Motor Vehicle Credit (PEDVC)--accounted for $895 million, or about 5 percent of total clean-energy tax credits awarded during the period studied. The bottom 80 percent of people filing for the PEDVC received little more than 10 percent of the benefits, and the bottom 90 percent of filers received only about 40 percent of credits.

Hybrids or Plug-ins?

Toyota continues to dominate the hybrid market worldwide shipping about a million new hybrid cars each year. Its sales have declined in the U.S. partly because of the nation's subsidies for plug-in cars. In Japan, it is far more successful with its hybrid sales because of different priorities of the Japanese government. The new version of the Prius was delayed deliberately by Toyota for more than a year which explains some of the decline in hybrid sales. The 2016 Prius offers an ECO model with an EPA rating of 56 MPG.

Honda lost the first round of hybrid competitions with Toyota because it did not keep up with Prius advances. But its more recent hybrid Accord, with a fuel economy rating of 47 MPG, is a major technical advance over its earlier product lines. Hyundai and Kia of South Korea have achieved significant hybrid sales success in the U.S. and recently announced a new line of high performance vehicles, the IONIQ, which will include three optional drive trains – hybrid, plug-in hybrid, and battery EV – bringing more competitive pressure to American car companies. GM has announced a Chevrolet Malibu hybrid version with an impressive 47 MPG rating, showing its recognition of the threat of hybrid cars to its sales of plug-ins. Ford's hybrid market share is in decline since its two main models, Fusion and C-max, were downgraded respectively to 42 and 40 MPG. The company will have to develop new hybrid models to maintain market share.

These new models from GM and Hyundai/Kia will be competing with a much advanced Prius drive train, which will gradually be incorporated in other Toyota hybrid models. Ford's strategy is unclear since Toyota has raised the bar significantly. GM efforts include the Malibu hybrid, along with plug-ins such as the new Volt and a new fully electric car, the Bolt. GM and Ford must compete better in the hybrid car market or be driven from it by Toyota and Hyundai/Kia.

Hybrid and Plug-in CO_2 Comparison of Top Models

Table 15 lists the top ten hybrid models in 2015 with the most sales (82% of total sales). Each model includes the CO_2 in grams per mile and the miles per gallon (MPG). The average grams of CO_2 per mile for the hybrids are 237 and the average MPG is 45.

Top 10 Hybrids in Sales – 2015				
Company	**Model**	**Sales Units**	**CO_2 grams /mile**	**MPG**
Toyota	Prius Lift-back	113,829	213	50
Toyota	Camry	39,515	260	41
Toyota	Prius c	38,484	213	50
Toyota	Prius v	28,290	254	42
Ford	Fusion	24,681	254	42
Hyundai	Sonata	19,908	281	38
Lexus	CT200h	14,657	254	42
Ford	C-max	14,177	267	40
Toyota	Avalon	11,956	267	40
Honda	Accord	11,065	227	47
Total		316,562		
Weighted Average CO_2 & MPG			237	45

Table 15: Weighted MPG and CO_2 for Top Ten Hybrid Cars in 2015

Tables 16 lists shows the top ten plug-in models in 2015 with the most sales (92% of total sales). The same technique is used as for the hybrid models. The fuel economy is given in MPGe units which do not include the energy to create electricity. (This is well covered in the car section of the Plan Curtail website). The average grams of CO_2 per mile for the plug-ins are 230 and the average MPGe is 92. As time goes by, more and more people will hopefully become familiar with the difference between MPG and MPGe and the misrepresentation implications.

Top 10 Plug-ins in Sales – 2015				
Company	**Model**	**Sales Units**	**CO_2 grams /mile**	**MPGe**
Tesla	Model S	26,400	250	89
Nissan	Leaf	17,269	190	114
Chevrolet	Volt	15,393	250	67
BMW	i3	11,024	200	124
Ford	Fusion-Eng	9,750	270	63
Ford	C-max-Eng	7,591	270	63
Fiat	500e	4,516	190	116
VW	e-golf	4,232	190	116
Toyota	PIP	4,191	220	72
Chevrolet	Spark	2,629	180	119
		102,995		
Weighted Average CO_2 & MPGe			230	92

Table 16: Weighted MPGe and CO_2 for Top Ten Plug-in Cars in 2015

Note the CO_2 emissions are very close for the two groups. As "climate friendly" cars, they are roughly equivalent. As time goes by, more and more people will become familiar with the different ways of measuring MPG and may insist on eliminating the confusion.

After five full years of plug-in sales, the car companies are bringing forth new improved models in 2016. At this time, it is possible to predict the coming competitive environment relative to emissions. Table 17 compares the CO_2 and the MPG/MPGe ratings of 2016 models. Of particular significance is the new Volt and the new Leaf which are the main competitors to the Prius. The new Tesla X is also included. Note that the competitive situation is not changed significantly – both architectures show a similar improvement in fuel economy.

New Hybrids – 2016					New Plug-ins – 2016			
Company	**Model**	**CO2/mile**	**MPG**		**Company**	**Model**	**CO2/mile**	**MPG**
Toyota	Prius Lift-back	205	52		Tesla	Model X	250	89
Toyota	Prius ECO	190	56		Nissan	Leaf 24kwh	190	114
					Chevrolet	Volt	220	74
					Nissan	Leaf 30kwh	200	112
Total								
Average CO_2/MPG		197	54		Average CO_2/MPGe		215	97

Table 17: CO_2 emissions of 2016 Hybrids and 2016 Plug-ins

Conclusions

After ten years of development and production, plug-in sales have been disappointing. The total plug-in hybrids (PHEVs) purchased through 2015 are slightly less than 200,000 units, about one fifth of the original Obama 2008 projection. Currently BEVs are gaining market share over PHEVs. The competition between hybrids, BEVs, and PHEVs will continue. New BEV models are adding more range which adds to their cost and decreases MPGe. But more range and more charging stations may not result in significant new orders.

The government subsidies are vital in supporting the plug-in market. Should these disappear, plug-in sales could plummet. The hybrids are not subsidized but must compete in the market without government assistance. Toyota and Hyundai/Kia are successfully doing so.

The disappointing news for 2015 was a decrease in the market share of hybrids and plug-ins relative to all cars. The share in 2015 was 3.1 percent, below the 3.2 percent in 2012. (See Table 1. In spite of increasing climate change concerns, citizens are not picking fuel efficient cars. This is particularly a concern since the plug-in cars have proven themselves in terms of reliability and fuel economy.

It is to be hoped that a new standard of transparency could develop relative to accurate measurements of plug-in car performance, today typically provided in MPGe. It is a trivial effort to provide CO_2 emissions as well. The automotive world was scandalized by the September 2015 acknowledgement that Volkswagen had provided special equipment to mislead consumers and regulators relative to emissions. This has led to a loss of trust in the company, which may incur significant financial losses as a result.[26] There have been other examples of performance misrepresentation, including Ford and Hyundai/Kia, which gave inflated MPG

numbers for their hybrid and electric cars. Hyundai/Kia paid $350 million dollars in fines and penalties.[27] Ford reimbursed their hybrid and EV owners.[28]

Yet to date, no one has measured the financial impact of the inflated MPGe numbers for plug-ins using methods developed by the EPA. The government should be held accountable for misrepresenting information just as the car companies have been. I predict at some point that the EPA will have to develop new window stickers that more accurately reflect actual performance in each part of the country, allocated by different fuel mixes for power plants. Full disclosure of all parameters may further limit plug-in sales. On the other hand, it could lead to higher plug-in sales in states with less CO_2 generated per kilowatt hour.

This report is on U.S. sales but a brief perspective on plug-in worldwide sales is in order. World production for all cars for the last ten years is displayed in Table 18. Worldwide car production continues to grow. There were about 500,000 plug-in cars shipped worldwide. Projections for total new vehicles are about 93 million vehicles. So plug-ins represent about one half of one percent of the total market.

Year	Volume (millions)		Year	Volume (millions)
2006	69		2011	80
2007	73		2012	84
2008	71		2013	87
2009	62		2014	90
2010	78		2015	92

Table 18: World Wide Light Vehicle Sales 2006-2015 [29]

Part of the plug-in decline may be relative to reduced gasoline prices. Figure 7 shows the change in crude oil prices as shown by the EIA from 2009 through 2015.[30] This time period covers the complete life span of plug-in cars and provides some justification for the declining sales.

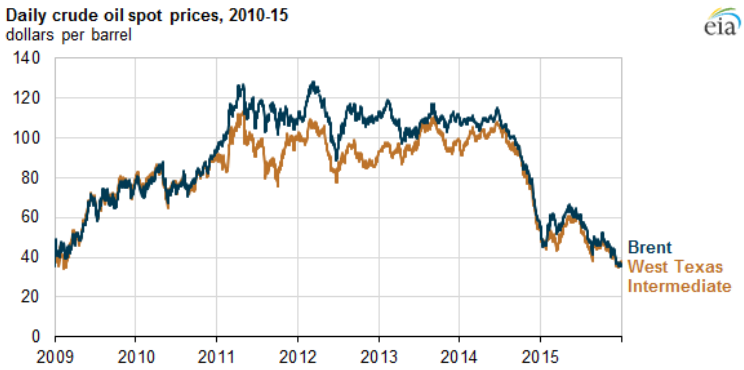

Figure 7: Crude Oil Prices 2009 – 2015

Is this a temporary setback for plug-ins or does it represent a long term trend? I think the latter. Unfortunately, plug-ins were initially oversold with inflated Mile per Gallon equivalent (MPGe) claims. Plug-in sales increased rapidly but have now flattened. The original idea was that the plug-in hybrid would be a revolutionary improvement over the conventional hybrid, which has

been disproven. A PHEV is a battery electric vehicle with a gasoline motor for charging the battery. Plug-ins did affect hybrid sales but the overriding fact is that both have lost popularity with the public. It will be hard to regain the original excitement. Whatever, the rationale, the public is not choosing cars based on climate considerations.

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